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CALIFORNIA ENERGY COMMISSION
1516 Ninth Street, MS-4
Sacramento, CA 95814

Reference Docket No. 07-BSTD-1

I wish to direct this discussion in reference to the 2008 Update to the Building Energy Efficiency Standards (45-day language). The portion that I direct your attention is the swimming pool system piping and is located at Subchapter 7, Section 150.p.2.C.(page 202 of the document).

"C. All elbows shall be sweep elbows or elbow-type fittings with a friction factor less than or equal to equivalent sweep elbows"

The wording of this statement is troubling because it is undefined and imprecise. What is the definition of an "equivalent sweep elbow" as stated? Since there is not a standardized definition of a sweep elbow to which a comparison is to be made, this paragraph does not have a quantitative measure or guideline. There is not currently a standardized method to derive the "friction factor" defined or referred to in this statement. The pipe fitting industry has used data developed decades ago by a manufacturer of iron fittings to calculate the head loss of various fittings and valves. This information is commonly referenced in engineering handbooks and manuals to this day[1]. In 2002, LASCO Fittings, Inc. commissioned the Center for Irrigation Technology[2], to evaluate the affect of replacing standard elbows with "sweep elbows" and submits this data for your consideration. The results of the testing illustrates that any reduction in friction head loss is trivial.

The Plastic Pipe Institute (PPI) a division of the Society of the Plastics Industry (SPI), and manufacturers of PVC pipe and fittings recommend that velocities within a piping be limited to 5 feet per second[3]. This serves multiple functions, the most common to reduce friction loss within the system. It is common practice in the process piping, irrigation and most hydraulic designs to reduce the **friction loss** and **energy requirements** by lowering the system flow velocity or by going to larger piping size. For example, using 2" Schedule 40 pipe (commonly used in swimming pools construction) and **reducing the flow velocity of 8 feet per second** (paragraph B of the same section) by just 1 foot per second, **will lower the friction loss** by ½ psi or about 12%.[4]

However, restricting the system velocity to 5 feet per second, as recommended by the industry, the friction loss in the complete system, not just the elbows, would be reduced by as much as 60%. There are many ways to reduce the flow velocities within a system, such as pump sizing, pump speed and piping size. In a system with 1½ inch piping flowing at 50 gallons per minute, or about 8 feet per second, just by increasing the piping one size, to 2 inch, the system witie friction loss would be decreased by as almost 70%. By limiting the flow velocity within a piping system, there is a quantitative method to work out the friction losses as compared to an undefined "equivalent sweep elbow".

The use of "sweeps" in place of elbows have not proven to provide the total energy savings perceived and can substantially increase the cost of swimming pools being built. Without a standardized test method, the irrigation and hydraulics industry rely on the information developed by Crane Co.[5] that represents the friction loss of various fittings in equivalent length of pipe. The attached testing conducted by the Center for Irrigation Technology (CIT), at California State University at Fresno, illustrates and corroborates the friction loss data of elbows. With that data, the difference between a standard 90° Elbow and a 90° long radius Elbow can be about to 30 diameters of pipe. Using 1½" piping, for example, the difference is 1.59" (actual I.D. diameter) x 30 = 47.7 inches of addition pipe. The friction loss of 48 inches of pipe at the flow velocity of 8 feet per second, the comparison of a standard and a "long sweep elbow" reveals a savings of less than ¼ psi or the equivalent of lowering the system velocity about one foot per second.

Then by using efficiency data for a pump commonly, used swimming pool illustrates that 1 psi savings would equate to 1/6 horsepower. The savings of ¼ psi would thus result in only .0.04 horsepower or 0.0298-kilowatt savings. Whereas using 2" piping, with the same gallon per minute flow, would yield a 0.020-kilowatt savings. This should illustrate that lowering the system velocity is a more effective and cost efficient method to save energy than requiring sweep elbows in swimming pool construction.

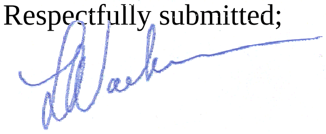
The design and construction of swimming pool systems with **lower flow rates** will provide a healthy, safe, and enjoyable addition to any residential property without undue construction cost increase while **lowering the energy requirements** to circulate the water properly.

I submit that the revised Section 150.2.B should be:

B. Pool piping shall be sized so that the velocity of the water at maximum flow for auxiliary pool loads does not exceed ~~eight~~ <u>five</u> feet per second in the return ~~line and six feet per second in the suction line; and~~ <u>or suction piping system</u>.

C. ~~All elbows shall be sweep elbows or elbow-type fittings with a friction factor less than or equal to an equivalent sweep elbow~~.

Respectfully submitted;



Larry Workman
National Product Manager

1. Standard Handbook for Mechanical Engineers, Baumeister & Marks, Seventh edition, pg 3-63
2. Center for Irrigation Technology (CIT), California State University at Fresno, Testing for LASCO Fittings, Inc. Jan, 2002, S4-406-3a, S4-D300-3a, & S4-D304-3a
3. Plastic Pipe Institute, a division of the Society of the Plastics Industry, Thermoplastic piping for Swimming Pool Water Circulation Systems, TR17
4. Plastic Pipe Institute, a division of the Society of the Plastics Industry, Water Flow characteristics of Thermoplastic Pipe, TR14
5. Crane Co., Technical Paper 410, Flow of Fluids

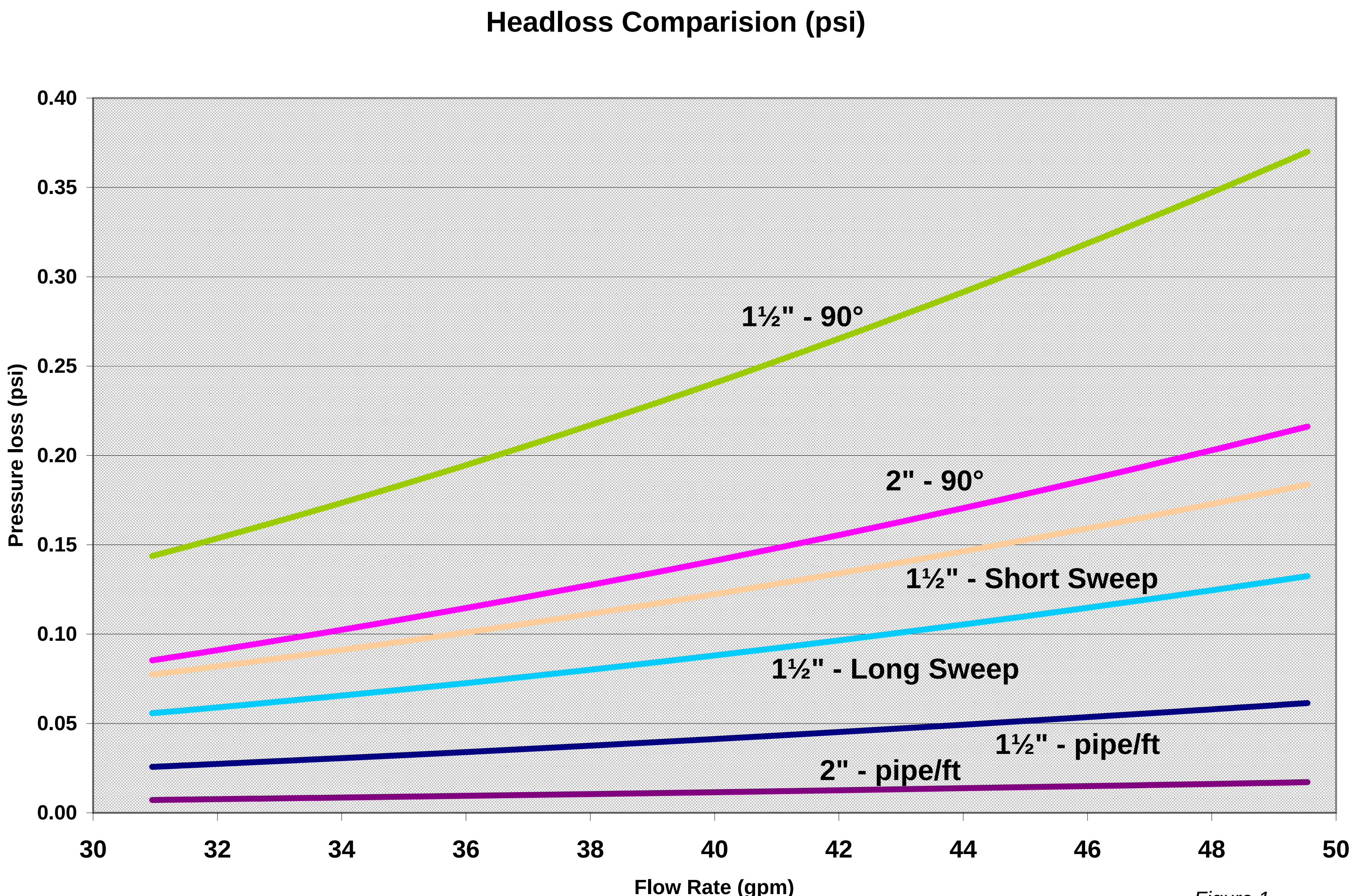

Headloss Comparision (psi)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Pressure loss (psi)
1½" - 90°
2" - 90°
1½" - Short Sweep
1½" - Long Sweep
1½" - pipe/ft
2" - pipe/ft
30
32
34
36
38
40
42
44
46
48
50
Flow Rate (gpm)

Figure 1

Composite of CIT Test Data

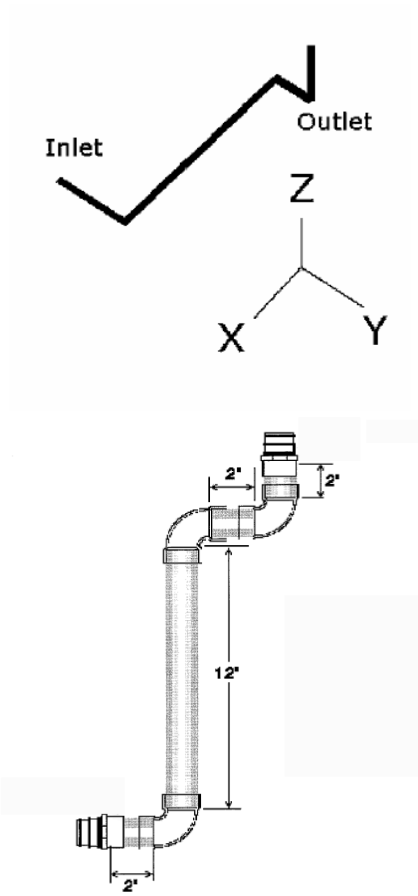
		Headloss (psi) Note A		
	406	$=0.0004631\mathbf{q}^2-0.000749\mathbf{q}+0.0106344$	⟵	1½" Standard Schedule 40 Elbow
1½"	D300	$=0.0002354\mathbf{q}^2-0.001791\mathbf{q}+0.0622547$	⟵	1½" Short Sweep (DWV style)
	D304	$=0.0001751\mathbf{q}^2-0.001717\mathbf{q}+0.0527348$	⟵	1½" Long Sweep (DWV Style)
2"	406	$=0.0002753\mathbf{q}^2-0.001054\mathbf{q}+0.024666$	⟵	2" Standard Schedule 40 Elbow

Velocity = $0.4085 \times q/D^2$

1½" Schedule 40 (i.d.) = 1.59

2" Schedule 40 (i.d.) = 2.067

	Headloss (psi)					
	1½ Inch				2 inch	
GPM	**Velocity**	**406**	**D300**	**D304**	**Velocity**	**406**
10	**1.62**	0.02	0.02	0.02	**0.96**	0.01
12	**1.94**	0.02	0.02	0.02	**1.15**	0.02
14	**2.26**	0.03	0.03	0.02	**1.34**	0.02
16	**2.59**	0.04	0.03	0.02	**1.53**	0.03
18	**2.91**	0.05	0.04	0.03	**1.72**	0.03
20	**3.23**	0.06	0.04	0.03	**1.91**	0.04
22	**3.55**	0.07	0.05	0.03	**2.10**	0.04
24	**3.88**	0.09	0.05	0.04	**2.29**	0.05
26	**4.20**	0.10	0.06	0.04	**2.49**	0.06
28	**4.52**	0.12	0.07	0.05	**2.68**	0.07
30	**4.85**	0.13	0.07	0.05	**2.87**	0.08
31	**5.00**	0.14	0.08	0.06	**2.96**	0.09
32	**5.17**	0.15	0.08	0.06	**3.06**	0.09
34	**5.49**	0.17	0.09	0.07	**3.25**	0.10
36	**5.82**	0.19	0.10	0.07	**3.44**	0.11
38	**6.14**	0.22	0.11	0.08	**3.63**	0.13
40	**6.46**	0.24	0.12	0.09	**3.82**	0.14
42	**6.79**	0.27	0.13	0.10	**4.02**	0.16
44	**7.11**	0.29	0.15	0.11	**4.21**	0.17
46	**7.43**	0.32	0.16	0.11	**4.40**	0.19
48	**7.76**	0.35	0.17	0.12	**4.59**	0.20
49.5	**8.00**	0.37	0.18	0.13	**4.74**	0.22
50	**8.08**	0.38	0.19	0.13	**4.78**	0.22



Note A:

i.) Data taken from testing performed at CIT for LASCO Feb-2002. Equations developed by using "best fit" analysis of the test data collected.

ii.) Information was based on an assembly of fittings that included 3 elbows of the styles listed and in the figure shown. The total headloss was then divided by 3 to obtain an average value.

Figure 2

Collected Test Data by CIT

1½" Elbows & Sweeps

S4-406-3a (1½" 90° Elbow)

Flow Rate (GPM)	Headloss (psi)
10.10	0.057
13.90	0.08
18.20	0.128
24.30	0.281
29.20	0.391
35.30	0.561
42.20	0.788
48.50	1.096
57.20	1.496
61.20	1.715
65.50	1.954
70.20	2.204
81.40	3.002
90.00	3.669
100.70	4.663

$Y=0.0004631q^2-0.000749q+0.0106344$

Curve Fitting — S4-406-3a

File Edit Help Calculator

Data Display/Editor
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X	Y
10.1	.057
13.9	.08
18.2	.128
24.3	.281
29.2	.391
35.3	.561
42.2	.788
48.5	1.096
57.2	1.496
61.2	1.715
65.5	1.954
70.2	2.204
81.4	3.002
90	3.669
100.7	4.663

Fit to 25 Equations => | Tabular Comparison | Graphical Comparison | Forecast | Fit to 3 Polynomials

Equations	Equation Coefficients a	b	c	Correlation Coefficient
Y=a+b*X	-.939489	.0483719	.	0.9382512
Y=b*X	.	.0338995	.	0.8327997
Y=1/(a+b*X)	10.10205	-.134452	.	0.5027747
Y=a+b*X+c/X	-2.27604	.0629634	19.41207	0.9788476
Y=a+b/X	2.666893	-38.0755	.	0.4409078
Y=X/(a*X+b)	-2.84398	198.9657	.	0.968186
Y=a+b/X+c/X^2	4.452524	-154.043	1156.246	0.7249697
Y=a+b*X+c*X^2	.0106344	-.000749	.0004631	0.9997543
Y=a*X+b*X^2	-.000329	.0004597	.	0.9897567
Y=a*X^b	.0004734	1.988988	.	0.9968193
Y=a*b^X	.0722844	1.048427	.	0.9124423
Y=a*b^(1/X)	.	.	.	0.
Y=a*X^(b*X)	.1106447	.0095217	.	0.8773707
Y=a*X^(b/X)	9.352863	-24.9411	.	0.9551784
Y=a*e^(b*X)	.0722844	.0472913	.	0.9124423
Y=a*e^(b/X)	3.819836	-51.2984	.	0.8814685
Y=a+b*lnX	-4.97351	1.735746	.	0.7250682
Y=1/(a+b*lnX)	27.95072	-6.61152	.	0.7830997
Y=a*b^X*X^c	.000593	1.002413	1.895992	0.9967957
Y=a*b^(1/X)*X^c	.0002194	118.7175	2.155716	0.9973831
Y=a*e^((X-b)^2/c)	3.900395	99.13495	-1949.80	0.9884809
Y=a*e^((lnX-b)^2/c)	.	.	.	0.
Y=a*X^b*(1-X)^c	.	.	.	0.
Y=a*(x/b)^c*e^(x/b)	54.52704	414.8771	1.895992	0.9967957
Y=1/(a*(X+b)^2+c)	.0038531	-70.4776	-1.13223	0.8023049

S4-D300-3a (1½" Short Sweep)

Flow Rate (GPM)	Headloss (psi)
9.30	0.065
13.50	0.086
20.50	0.109
27.40	0.187
34.80	0.304
40.80	0.384
50.10	0.579
55.00	0.688
60.10	0.771
67.50	0.989
77.40	1.341
87.70	1.738
90.00	1.812
100.10	2.23

$Y=0.0002354q^2-0.001791q+0.0622547$

Curve Fitting — S4-D300-3a

File Edit Help Calculator

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X	Y
9.3	.065
13.5	.086
20.5	.109
27.4	.187
34.8	.304
40.8	.384
50.1	.579
55	.688
60.1	.771
67.5	.989
77.4	1.341
87.7	1.738
90	1.812
100.1	2.23

Fit to 25 Equations => | Tabular Comparison | Graphical Comparison | Forecast | Fit to 3 Polynomials

Equations	Equation Coefficients a	b	c	Correlation Coefficient
Y=a+b*X	-.427240	.0235145	.	0.9343456
Y=b*X	.	.0172184	.	0.8522517
Y=1/(a+b*X)	11.01723	-.134844	.	0.6762068
Y=a+b*X+c/X	-1.06777	.0304525	8.902155	0.9780585
Y=a+b/X	1.331375	-16.9053	.	0.4003919
Y=X/(a*X+b)	-1.20306	165.6495	.	0.9707448
Y=a+b/X+c/X^2	2.196630	-72.9782	513.3655	0.7036438
Y=a+b*X+c*X^2	.0622547	-.001791	.0002354	0.9993781
Y=a*X+b*X^2	.0006347	.0002157	.	0.9893844
Y=a*X^b	.0012592	1.584342	.	0.9712393
Y=a*b^X	.0617893	1.040005	.	0.9620915
Y=a*b^(1/X)	.	.	.	0.
Y=a*X^(b*X)	.0871205	.0079296	.	0.9375309
Y=a*X^(b/X)	3.140376	-19.0057	.	0.8763751
Y=a*e^(b*X)	.0617893	.039226	.	0.9620915
Y=a*e^(b/X)	1.520930	-36.8779	.	0.7664107
Y=a+b*lnX	-2.31999	.8323053	.	0.7050484
Y=1/(a+b*lnX)	27.35495	-6.23295	.	0.9201348
Y=a*b^X*X^c	.006734	1.018527	.8815732	0.9920499
Y=a*b^(1/X)*X^c	.0000395	84776108	2.336068	0.9977115
Y=a*e^((X-b)^2/c)	2.478031	122.7125	-3515.85	0.9969173
Y=a*e^((lnX-b)^2/c)	.0445136	1.278301	2.782972	0.995845
Y=a*X^b*(1-X)^c	.	.	.	0.
Y=a*(x/b)^c*e^(x/b)	.2284816	54.47369	.8815732	0.9920499
Y=1/(a*(X+b)^2+c)	.0031864	-74.9152	-.239424	0.9420912

S4-D304-3a (1½" Long Sweep)

Flow Rate (GPM)	Headloss (psi)
10.20	0.056
13.50	0.063
24.90	0.109
32.80	0.181
39.10	0.259
45.40	0.355
53.40	0.441
59.90	0.599
71.60	0.813
83.50	1.149
90.00	1.313
109.40	1.969

$Y=0.0001751q^2-0.001717q+0.0527348$

Curve Fitting — S4-D304-3a

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X	Y
10.2	.056
13.5	.063
24.9	.109
32.8	.181
39.1	.259
45.4	.355
53.4	.441
59.9	.599
71.6	.813
83.5	1.149
90	1.313
109.4	1.969

Fit to 25 Equations => | Tabular Comparison | Graphical Comparison | Forecast | Fit to 3 Polynomials

Equations	Equation Coefficients a	b	c	Correlation Coefficient
Y=a+b*X	-.365048	.0184434	.	0.9198698
Y=b*X	.	.0132072	.	0.8284951
Y=1/(a+b*X)	13.60534	-.159144	.	0.6561148
Y=a+b*X+c/X	-.941105	.0244278	8.388512	0.9759802
Y=a+b/X	1.035918	-13.7750	.	0.3473325
Y=X/(a*X+b)	-1.42373	213.7188	.	0.9721907
Y=a+b/X+c/X^2	1.899351	-71.8483	563.3051	0.687103
Y=a+b*X+c*X^2	.0527348	-.001717	.0001757	0.9994211
Y=a*X+b*X^2	.0001854	.0001615	.	0.9894269
Y=a*X^b	.000992	1.565912	.	0.9646469
Y=a*b^X	.0498874	1.037889	.	0.9598544
Y=a*b^(1/X)	.	.	.	0.
Y=a*X^(b*X)	.0703266	.0074184	.	0.9324335
Y=a*X^(b/X)	2.297747	-18.9411	.	0.8576268
Y=a*e^(b*X)	.0498874	.0371897	.	0.9598544
Y=a*e^(b/X)	1.141964	-37.6412	.	0.7537147
Y=a+b*lnX	-1.89660	.6670531	.	0.6558798
Y=1/(a+b*lnX)	34.40591	-7.77527	.	0.9225933
Y=a*b^X*X^c	.0058264	1.018534	.8363692	0.9911177
Y=a*b^(1/X)*X^c	.0000187	32207594	2.422877	0.9983641
Y=a*e^((X-b)^2/c)	2.224409	135.0962	-4179.94	0.9973068
Y=a*e^((lnX-b)^2/c)	.0399902	1.485249	2.591540	0.995791
Y=a*X^b*(1-X)^c	.	.	.	0.
Y=a*(x/b)^c*e^(x/b)	.1649491	54.45242	.8363692	0.9911177
Y=1/(a*(X+b)^2+c)	.0033679	-80.9978	-.482097	0.9414996

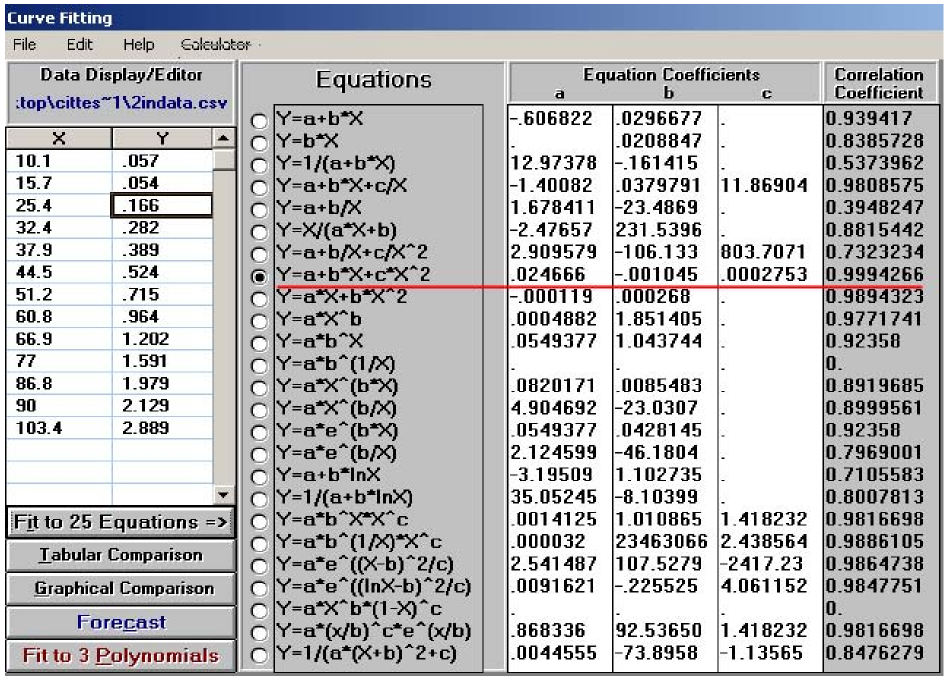
Screen prints of data evualation done with Kurv+

Figure 3

Collected Test Data by CIT

2" Elbows

Flow Rate (GPM)	Headloss (psi)
S4-406-4a (2" 90°)	
10.10	0.057
15.70	0.054
25.40	0.166
32.40	0.282
37.90	0.389
44.50	0.524
51.20	0.715
60.80	0.964
66.90	1.202
77.00	1.591
86.80	1.979
90.00	2.129
103.40	2.889



Curve Fitting

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X	Y
10.1	.057
15.7	.054
25.4	.166
32.4	.282
37.9	.389
44.5	.524
51.2	.715
60.8	.964
66.9	1.202
77	1.591
86.8	1.979
90	2.129
103.4	2.889

Fit to 25 Equations =>

Tabular Comparison

Graphical Comparison

Forecast

Fit to 3 Polynomials

Equations	Equation Coefficients a	b	c	Correlation Coefficient
Y=a+b*X	-.606822	.0296677	.	0.939417
Y=b*X	.	.0208847	.	0.8385728
Y=1/(a+b*X)	12.97378	-.161415	.	0.5373962
Y=a+b*X+c/X	-1.40082	.0379791	11.86904	0.9808575
Y=a+b/X	1.678411	-23.4869	.	0.3948247
Y=X/(a*X+b)	-2.47657	231.5396	.	0.8815442
Y=a+b/X+c/X^2	2.909579	-106.133	803.7071	0.7323234
Y=a+b*X+c*X^2	.024666	-.001045	.0002753	0.9994266
Y=a*X+b*X^2	-.000119	.000268	.	0.9894323
Y=a*X^b	.0004882	1.851405	.	0.9771741
Y=a*b^X	.0549377	1.043744	.	0.92358
Y=a*b^(1/X)	.	.	.	0.
Y=a*X^(b*X)	.0820171	.0085483	.	0.8919685
Y=a*X^(b/X)	4.904692	-23.0307	.	0.8999561
Y=a*e^(b*X)	.0549377	.0428145	.	0.92358
Y=a*e^(b/X)	2.124599	-46.1804	.	0.7969001
Y=a+b*lnX	-3.19509	1.102735	.	0.7105583
Y=1/(a+b*lnX)	35.05245	-8.10399	.	0.8007813
Y=a*b^X*X^c	.0014125	1.010865	1.418232	0.9816698
Y=a*b^(1/X)*X^c	.000032	23463066	2.438564	0.9886105
Y=a*e^((X-b)^2/c)	2.541487	107.5279	-2417.23	0.9864738
Y=a*e^((lnX-b)^2/c)	.0091621	-.225525	4.061152	0.9847751
Y=a*X^b*(1-X)^c	.	.	.	0.
Y=a*(x/b)^c*e^(x/b)	.868336	92.53650	1.418232	0.9816698
Y=1/(a*(X+b)^2+c)	.0044555	-73.8958	-1.13565	0.8476279

Y= $0.0002753q^2$ -0.001045q +0.024666

Screen prints of data evualation done with Kurv+

Figure 4

Calculated Headloss Comparison

Based on test data developed by CIT

Headloss: (ft/100ft)

$f = .2083 \times (100/C)^{1.852} \times (q^{1.852}/d^{4.8655})$ Hazen -Williams

$(100/150)^{1.852}$ = 0.47193

$1/1.852$ = 0.53996

	1½"	**2"**
$d^{4.8655}$ =	9.54768	34.22072

	Headloss (psi)							
	1½ Inch					2 inch		
GPM	**Velocity**	**Pipe/ft**	**90°**	**Short Sweep**	**Long Sweep**	**Velocity**	**Pipe(ft)**	**90°**
30.95	5.001019	0.025696	0.143686	0.077438	0.055774	2.959183	0.007169	0.085345
32	5.170682	0.027334	0.153627	0.081997	0.059031	3.059575	0.007626	0.091044
34	5.493849	0.030581	0.173504	0.091161	0.065591	3.250798	0.008532	0.102461
36	5.817017	0.033996	0.194616	0.100952	0.072617	3.442022	0.009485	0.114612
38	6.140184	0.037577	0.216963	0.111371	0.080111	3.633245	0.010484	0.127496
40	6.463352	0.041321	0.240545	0.122418	0.088072	3.824469	0.011529	0.141115
42	6.78652	0.045229	0.265362	0.134093	0.096499	4.015692	0.012619	0.155468
44	7.109687	0.049298	0.291413	0.146395	0.105393	4.206915	0.013754	0.170556
46	7.432855	0.053529	0.318700	0.159325	0.114755	4.398139	0.014935	0.186377
48	7.756022	0.057918	0.347222	0.172883	0.124583	4.589362	0.016159	0.202932
49.54	8.004861	0.061407	0.370025	0.183750	0.132469	4.736604	0.017133	0.216180

		Equivalent Diameters of pipe		
GPM	**Velocity**	**90°**	**Short Sweep**	**Long Sweep**
30.95	5.0010186	42.2	22.7	16.4
32	5.1706815	42.4	22.6	16.3
34	5.4938491	42.8	22.5	16.2
36	5.8170167	43.2	22.4	16.1
38	6.1401843	43.6	22.4	16.1
40	6.4633519	43.9	22.4	16.1
42	6.7865195	44.3	22.4	16.1
44	7.1096871	44.6	22.4	16.1
46	7.4328547	44.9	22.5	16.2
48	7.7560223	45.2	22.5	16.2
49.54	8.0048614	45.5	22.6	16.3

Figure 4

Test Specimens at CIT